FM IBOC System Evaluation Matrix – Lab Tests – rev. 4

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
F	**IBOC "digital-to-analog" compatibility performance**									
1)	Co-channel interference									
2)	Single 1st-adjacent channel interference									
3)	Simultaneous upper and lower 1st-adjacent channel interference									
4)	Single 2nd-adjacent channel interference									✓
5)	Single 2nd-adjacent channel interference w/1st adj. channel interference									
6)	Simultaneous upper and lower 2nd-adjacent channel interference									
G	**IBOC "digital-to-analog" compatibility performance in a multipath fading channel**									
1)	Co-channel interference									
2)	Single 1st-adjacent channel interference									
3)	Simultaneous upper and lower 1st-adjacent channel interference									
4)	Single 2nd-adjacent channel interference									✓
5)	Single 2nd-adjacent channel interference w/1st adj. channel interference									
6)	Simultaneous upper and lower 2nd-adjacent channel interference									
H	**IBOC "analog-to-digital" compatibility performance**									
1)	Single 1st-adjacent channel interference									
2)	Simultaneous upper and lower 1st-adjacent channel interference		✓	✓		✓	✓	✓		
3)	Single 2nd-adjacent channel interference									

FM IBOC System Evaluation Matrix – Lab Tests – rev. 4

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
I	**IBOC "analog-to-digital" compatibility performance in a multipath fading channel**									
1)	Single 1st-adjacent channel interference		✓	✓		✓	✓	✓		
2)	Simultaneous upper and lower 1st-adjacent channel interference									
3)	Single 2nd-adjacent channel interference									
4)	Simultaneous upper and lower 2nd-adjacent channel interference									
J	**IBOC acquisition/re-acquisition performance**									
1)	Short interruption, linear channel									
2)	Long interruption , linear channel									
3)	Short interruption, linear channel, AWGN									
4)	Long interruption, linear channel, AWGN									
5)	Short interruption, linear channel, 1st-adj. channel interference									
6)	Long interruption, linear channel, 1st-adj. channel interference				✓					
7)	Short interruption, fading channel									
8)	Long interruption, fading channel									
9)	Short interruption, AWGN, fading channel									
10)	Long interruption, AWGN, fading channel									
11)	Short interruption, fading channel, 1st-adj. channel interference									
12)	Long interruption, fading channel, 1st-adj. channel interference									

FM IBOC System Evaluation Matrix – Lab Tests – rev. 4

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
K	**DAB quality**									
1)	Subjective assessment report of unimpaired IBOC audio quality (linear channel) versus analog FM	✓								
2)	"Long-form" DAT through IBOC system									
L	**IBOC "digital-to-host analog" compatibility performance**									
1)	Host analog main channel audio performance versus presence or absence of IBOC digital signal energy									
2)	Host analog main channel audio performance versus presence or absence of IBOC digital signal energy								✓	
3)	Host subcarrier audio and/or data performance versus presence or absence of IBOC digital signal energy									
4)	Host subcarrier audio and/or data performance versus presence or absence of IBOC digital signal energy									
M	**IBOC "host analog-to-digital" compatibility performance**									
1)	Digital audio, data transmission performance versus percent modulation of analog host signal			✓		✓				
2)	Digital audio, data transmission performance versus percent modulation of analog host signal									

FM IBOC System Evaluation Matrix – Field Tests – rev. 4

Notes:

- A checkmark ("✓ ") indicates that the results from a particular test are expected to apply to the indicated evaluation criteria.
- Test A (Calibration) provides a quality check on system testing as a whole and is not used directly for system evaluation.
- Columns marked "IBOC" represent criteria evaluated using IBOC receiver; those marked "ANALOG" represent criteria evaluated using analog (i.e. non-IBOC) receiver.

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
B	**Strong signal with low interference**									
1)	Low multipath		✓	✓		✓	✓	✓		
2)	Strong multipath									
3)	Host main channel audio compatibility								✓	
4)	Host analog 67 kHz and 92 kHz subcarrier compatibility									
C	**Single interferer**									
1)	Single 1st-adjacent channel interferer (at FCC limit)									
2)	Single 1st-adjacent channel interferer (at FCC limit) with multipath		✓	✓		✓	✓	✓		✓
3)	Single 1st-adjacent channel interferer (above FCC limit)									
4)	Single 1st-adjacent channel interferer (above FCC limit) with multipath									
D	**Two interferers**									
1)	Two simultaneous 1st-adjacent channel interferers (at FCC limit)									
2)	Two simultaneous 1st-adjacent channel interferers (at FCC limit) with multipath		✓	✓		✓	✓	✓		
3)	Two simultaneous 2nd-adjacent channel interferers									
4)	Two simultaneous 2nd-adjacent channel interferers (with multipath)									

AM IBOC System Evaluation matrix – Lab tests – rev. 4

Notes:

- A checkmark ("✓ ") indicates that the results from a particular test are expected to apply to the indicated evaluation criteria.
- Test A (Calibration) provides a quality check on system testing as a whole and is not used directly for system evaluation.
- Columns marked "IBOC" represent criteria evaluated using IBOC receiver; those marked "ANALOG" represent criteria evaluated using analog (i.e. non-IBOC) receiver.

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
B	**IBOC system performance with AWGN**									
1)	Linear channel, no interferers		✓	✓		✓	✓	✓		
C	**IBOC system performance with special impairments**									
1)	Impulse noise			✓		✓	✓	✓		
2)	Weak signal		✓							
D	**IBOC "digital-to-digital" compatibility performance**									
1)	Co-channel interference		✓	✓		✓	✓	✓		
2)	Single 1st-adjacent channel interference									
3)	Simultaneous upper and lower 1st-adjacent channel interference									
4)	Single 2nd-adjacent channel interference									
5)	Simultaneous upper and lower 2nd-adjacent channel interference									
6)	Single 3rd-adjacent channel interference									
F	**IBOC "digital-to-analog" compatibility performance**									
1)	Co-channel interference									
2)	Single 1st-adjacent channel interference									✓
3)	Single 2nd-adjacent channel interference									

AM IBOC System Evaluation matrix – Lab tests – rev. 4

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
H	**IBOC "analog-to-digital" compatibility performance**									
1)	Co-channel interference									
2)	Single 1st-adjacent channel interference									
3)	Simultaneous upper and lower 1st-adjacent channel interference		✓	✓		✓	✓	✓		
4)	Single 2nd-adjacent channel interference									
3)	Simultaneous upper and lower 2nd-adjacent channel interference									
J	**IBOC acquisition/re-acquisition performance**									
1)	Short interruption, linear channel									
2)	Long interruption , linear channel				✓					
3)	Short interruption, linear channel, AWGN									
4)	Long interruption, linear channel, AWGN									
K	**DAB quality**									
1)	Subjective assessment report of unimpaired IBOC audio quality (linear channel) versus analog AM (and optionally, analog FM)	✓								
2)	"Long form" DAT through IBOC system									
L	**IBOC "digital-to-host analog" compatibility performance**									
1)	Host analog main channel audio performance versus presence or absence of IBOC digital signal energy								✓	
M	**IBOC "host analog-to-digital" compatibility performance**									
1)	Digital audio, data transmission performance versus percent modulation of analog host signal			✓		✓				

AM IBOC System Evaluation matrix – Lab tests – rev. 4

Notes:

- A checkmark ("✓ ") indicates that the results from a particular test are expected to apply to the indicated evaluation criteria.
- Test A (Calibration) provides a quality check on system testing as a whole and is not used directly for system evaluation.
- Columns marked "IBOC" represent criteria evaluated using IBOC receiver; those marked "ANALOG" represent criteria evaluated using analog (i.e. non-IBOC) receiver.

		RECEIVER UNDER TEST								
		IBOC							ANALOG	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA-BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
B	**System performance within protected contour and low interference (day)**									
1)	Low interference (daytime)		✓	✓		✓	✓	✓		
2)	Performance with fading (daytime)									
3)	Performance with fading (nighttime)									
4)	Host main channel audio compatibility								✓	
C	**System performance within protected contour (day and night)**									
1)	Daytime performance over entire day coverage area.		✓	✓		✓	✓	✓		
2)	Nighttime performance over entire nighttime coverage area.									
3)	Daytime performance over entire day coverage area with fading.									
4)	Nighttime performance over entire nighttime coverage area with fading.									

Appendix F –
LDR submission – tests submitted

Laboratory test data (FM):

		CHANNEL				INTERFERERS *D/U in dB*					
NO.	ITEM	AWGN	LINEAR	NON-LINEAR	FADING	CO-CHAN	1ST-ADJ	2ND-ADJ	DATA	GRAPHS	COMMENTS
3	Multipath fading, no interferers				RF				Appendix F.1, pg. 5 (in text)	Fig. F1-1 (pg. 3) – analog comparison also shown	• Subjectively evaluated (ACR vs. distance) • Noise not actually added; signal strength reduced instead • No audio processing on IBOC audio • Analog benchmark data also obtained (only mobile receivers used for fading tests)
4	Multipath fading, 1st adj. channel interference				?		6 -1.5 -9			Fig. F1-2 (pg. 7) – analog comparison also shown	
					RF		?		Appendix F.4, Table 7		
K	DAB quality										
1	Subjective assessment report of unimpaired IBOC audio quality versus analog FM		✓							Appendix F.3, Figures 1, 2	• PAC evaluated – bit rate unknown, presence or absence of IBOC modulation unknown • Audio materials listed in Appendix F.3, pg. 3, Table 1 • Analog benchmark data also obtained

Laboratory test data (FM, cont.):

		CHANNEL				INTERFERERS *D/U in dB*					
NO.	ITEM	AWGN	LINEAR	NON-LINEAR	FADING	CO-CHAN	1ST-ADJ	2ND-ADJ	DATA	GRAPHS	COMMENTS
1	IBOC/Analog Compatibility (cont.)										
1	Host analog main channel audio performance vs. presence or absence of IBOC (linear channel)		✓						(Results summarized on pgs. 4-5 of Appendix G)	Appendix G, Figs. 1a, 1b (pg. 10), Figs. 2a, 2b (pgs. 11, 12)	• 5 analog receivers used • Subj. evaluated
			✓						Appendix F.4, Table 3 (1st Table 3, pg. 7)	Appendix F.4, Fig. 1 (pg. 6)	• 4 analog receivers used • Subj. evaluated vs signal strength – IBOC carriers always on
2	Host analog main channel audio performance vs. presence or absence of IBOC (fading channel)				US UF RF TO				(Results summarized on pgs. 4-5 of Appendix G)	Appendix G, Figs. 1a, 1b (pg. 10), Figs. 2a, 2b (pgs. 11, 12)	• 5 analog receivers used • Subj. evaluated
*	Host analog main channel audio performance with fading				RF				Appendix F.4, Table 3 (2nd Table 3, pg. 9)	Appendix F.4, Fig. 2 (pg. 8)	• 2 receivers used (both automotive) • Subj. evaluated – IBOC carriers always on
*	Host analog main channel audio performance with 1st adj. interference		✓				+31 +18.5 +6 −1.5 -9		Appendix F.4, Table 4 (pg. 10)		
					RF				Appendix F.4, Table 5 (pg. 11)		
*	Host analog main channel audio performance vs. output SNR (AWQP) ??		✓		RF				Appendix F.4, Table 6 (pg. 12)		• 6 receivers • Subj. evaluated – IBOC carriers always on

* indicates test not specified by NRSC's test guidelines.

Field test data (FM):

		CHANNEL				INTERFERERS *D/U in dB*					
NO.	ITEM	AWGN	LINEAR	NON-LINEAR	FADING	CO-CHAN	1ST-ADJ	2ND-ADJ	DATA	GRAPHS	COMMENTS
[illegible]	[illegible]										
1	Low multipath				✓				("Audio field test sampler" audio file – cut 9, described in Appendix K)		• Host stations: WBJB-FM, WPST-FM • Multi-streaming PAC at 128 kbps demonstrated
2	Strong multipath				✓						
C	Single interferer:										
1	Single 1st-adjacent channel interferer (at FCC limit)						✓		("Audio field test sampler" audio file – cut 9, described in Appendix K)		• Host stations: WBJB-FM, WPST-FM • Multi-streaming PAC at 128 kbps demonstrated
3	Single 1st-adjacent channel interferer (above FCC limit)						✓				

Laboratory test data (AM):

		CHANNEL				INTERFERERS *D/U in dB*					
NO.	ITEM	AWGN	LINEAR	NON-LINEAR	FADING	CO-CHAN	1ST-ADJ	2ND-ADJ	DATA	GRAPHS	COMMENTS
B	IBOC system performance with AWGN										
1	Linear channel, no interferers		✓						Table J-1, pg. 6		• FER vs. S/N (FER given by stream) • Analog audio restricted to ± 4.5 kHz (all tests)
C	IBOC system performance with special impairments										
2	Weak signal		✓						Table J-2, pg. 7		FER vs. signal level (FER given by stream)
D	IBOC system adjacent channel performance										
1	Co-channel		✓			+28 +27 +26 +25 +23 +21			Table J-3, pg. 8		• FER vs. co-channel D/U (FER given by stream) • Both desired and undesired are IBOC carriers
3	Dual 1st-adj.		✓				(2) +22 +21 +20 +19 +18 +17		Table J-5, pg. 11		• 1st adj. interferers are IBOC with ± 4.5 kHz analog • Upper and lower 1st adj. at same level • FER vs. dual 1st-adj. channel D/U (FER given by stream)

Laboratory test data (AM, cont.):

NO.	ITEM	CHANNEL				INTERFERERS *D/U in dB*			DATA	GRAPHS	COMMENTS
		AWGN	LINEAR	NON-LINEAR	FADING	CO-CHAN	1ST-ADJ	2ND-ADJ			
[illegible]											
3	Dual 1st-adj.		✓				(2) +7 +6 +5 +4 +3 +2		Table J-4, pg. 10		• 1st adj. interferers are analog (not IBOC) and band limited to ± 4.5 kHz • FER vs. dual 1st-adj. channel D/U (FER given by stream)
D/H	IBOC compatibility [illegible]										
*			✓				+23 +21 +20 +17 +16 +15 +8 +6 +3	+20 +10 0	Table J-6, pg. 13		· 1st adj. interferer is analog (not IBOC), and band limited to ± 4.5 kHz ; 2nd adj. interferer is IBOC · Various combinations of 1st, 2nd adj. chnl. D/U tested · FER vs. D/U (FER given by stream)

* indicates test not specified by NRSC's test guidelines.

Field test data (AM):

		CHANNEL				INTERFERERS *D/U in dB*					
NO.	ITEM	AWGN	LINEAR	NON-LINEAR	FADING	CO-CHAN	1ST-ADJ	2ND-ADJ	DATA	GRAPHS	COMMENTS

(no data submitted)

Appendix G –
LDR comments on this evaluation report

(Attachment 4)

COMMENTS OF LUCENT DIGITAL RADIO CONCERNING NRSC DAB SUBCOMMITTEE EVALUATION OF ITS FM AND AM IBOC SYSTEM TESTS

Lucent Digital Radio ("LDR"), a subsidiary of Lucent Technologies, Inc., is the developer of digital radio systems that will enable AM and FM broadcasters to deliver new and better services to the American public.

LDR's systems utilize patented Multi-Streaming PAC™ technology to achieve clear digital reception even in the crowded signal conditions that will exist during the transition to digital. PAC™ also is being used for digital audio broadcasts delivered by satellite ("SDARS"). This commonality ensures the highest reception quality of both satellite and terrestrial digital radio, and will result in economies of scale in the receiver marketplace that will lower costs, accelerate the digital broadcast revolution, and directly benefit consumers.

LDR's in-band, on-channel (IBOC) systems for AM and FM each consist of two related designs. One, hybrid IBOC, permits broadcasters to initiate digital service using their current spectrum while continuing to transmit today's analog signals to their listeners with no noticeable impairment. The prototypes of these hybrid IBOC systems are the subjects of the attached Report by the National Radio Systems Committee ("NRSC") Digital Audio Broadcasting (DAB) Subcommittee. LDR's other system is all-digital. It is being designed to be compatible with LDR's hybrid IBOC system, and will provide a seamless transition from hybrid to all-digital modes so that consumers will attain the benefits of increased capacity and expanded data opportunities at the completion of the transition from analog to digital.

LDR believes and continues to advocate that system evaluations require testing that is conducted by third parties under strict identical circumstances. Using such a process, a system can be compared rapidly and efficiently both to existing analog and to competing digital systems. For all parties involved, such testing will save much expense and time, and provide a technically valid basis for evaluating all aspects of the proponent systems.

Although LDR's arguments for third party controlled testing were not adopted by the NRSC DAB Subcommittee for the initial tests addressed in this report, at its January, 2000, meeting the NRSC DAB Subcommittee voted to go forward to a standardization process for an IBOC standard if the first test results are sufficient. The test results show the great potential of IBOC, and we expect this future process to proceed by consensus and to include laboratory, field, and subjective comparative testing at an independent laboratory, such as the Advanced Television Testing Center (ATTC), or similar independent facility. We are confident that such testing will confirm our very favorable results.

In the time period provided for the recently completed phase of testing, LDR did the testing that it could accomplish within the context of its overall developmental effort and its need to simultaneously address issues raised by the Federal Communications Commission in its Notice of Proposed Rulemaking (which was released on November 1, 1999). LDR focused its testing upon those elements that would best reveal the quality and robustness of its hybrid IBOC system, and submitted substantial data to the Subcommittee. This included a significant amount of subjective test data, which shows the LDR IBOC system to have superior audio performance to analog FM. Subjective

tests are likely to more precisely indicate the preferences of customers, and when combined with objective measurements can be a good aid in system design.

In its report, the Subcommittee concludes that the tests indicate the reasonable probability of substantial improvement for broadcast listening when compared to the performance of analog AM and FM. LDR wishes to add that the substantial data capacity of its systems also will be of great benefit to the broadcasters' audiences. The many test systems that we have deployed in field testing gives us great confidence that our systems based upon Multi-Streaming PAC™ will be superior to today's analog systems. Our tests demonstrate the clear superiority of LDR's digital system, both for audio and with regard to the new services facilitated by the system's data capabilities.

Consumers can benefit from the increased audio quality and new data services made possible by LDR's digital system without the Federal Communications Commission (FCC) having to allocate a single kilohertz of new spectrum. This fact has the potential of shaving years off the time that otherwise would be needed to implement a new-band terrestrial digital radio broadcasting.

LDR continues to innovate its systems and to conduct additional testing. In April, 2000, over-the-air testing and demonstrations are being conducted in Las Vegas, Nevada, in conjunction with the National Association of Broadcasters (NAB) convention at which this report is being issued.

We believe in private industry initiatives, but also recognize the necessary role of the FCC as spectrum manager and regulator. We will continue to participate actively in the Subcommittee's work and to keep the FCC fully informed.

To the greatest extent feasible, industry itself should evaluate digital broadcast system options and ascertain the service features that will best meet the future needs of broadcasters, manufacturers, and the public. We are confident that the LDR hybrid IBOC and all-digital systems are the superior systems upon which to base new digital broadcast standards for the 21st Century. The attached report is the first step in that direction.